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A Decision Aid for Addressing Supervisor Span of Control Problems

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ARI Field Unit at Fort Leavenworth, Kansas

U. S. Army
Research Institute for the Behavioral and Social Sciences

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In 1982, the Fort Sill Field Unit of the Army Research Institute (ARI) developed a method for estimating how many launchers a Corps Support Weapon System (CSWS) platoon leader will be able to control. The Director of the CSWS Special Task Force was concerned with the tradeoff between number of launchers controlled and platoon leader workload. Although having each platoon leader control many launchers would conserve resources, it would also

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increase workload. At some point, the number of launchers would exceed what the platoon leader could adequately control, he would fall behind in completing his tasks, and the performance of the platoon would suffer.

To address the issue of platoon leader span of control, the Field Unit developed a computer-based simulation model that can be used to predict the platoon leader's ability to keep up with his work. The simulation model consists of two components. The first component is a task library, the second a computer program that operates upon the data contained in the library. This report describes the development of the simulation model, some findings generated when we ran the model to estimate the span of control for CSWS platoon leaders, and the uses to which the model could be put by system developers.

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A Decision Aid for Addressing Supervisor Span of Control Problems

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FOREWORD

In 1982, the Fort Sill Field Unit of the U.S. Army Research Institute (ARI) developed a method for estimating how many launchers a Corps Support Weapon System (CSWS) platoon leader will be able to control. To address the issue of platoon leader span of control, the Field Unit developed a computer-based simulation model that predicts platoon leader performance under various levels of task load. This report describes the development of the simulation model, some findings generated by the model when it was used to estimate the span of control for CSWS platoon leaders, and the uses to which the model could be put by system developers. The research was conducted as part of an effort to develop tools for the analysis of new weapon systems.

Edgar M. Johnson

EDGAR M. JOHNSON
Technical Director

A DECISION AID FOR ADDRESSING SUPERVISOR SPAN OF CONTROL PROBLEMS

EXECUTIVE SUMMARY

Requirement:

In 1982, the Fort Sill Field Unit of the Army Research Institute (ARI) developed a method for estimating how many launchers a Corps Support Weapon System (CSWS) platoon leader will be able to control. The Director of the CSWS Special Task Force was concerned with the tradeoff between number of launchers controlled and platoon leader workload. To conserve resources, it would be desirable to have each platoon leader control many launchers. Increasing the number of launchers controlled, however, would also increase workload. At some point, the number of launchers would exceed what the platoon leader could adequately control, he would fall behind in completing his tasks, and the performance of the platoon would suffer. No direct empirical data could be obtained since the CSWS was still at the concept development phase, and an alternative source of data was required.

Procedure:

A computer-based simulation model was developed to address the tradeoff between number of launchers controlled and platoon leader workload. The computer-based model consists of two components: (a) a task library and (b) a computer program that operates upon the data contained in the library. The task library consists of a list of tasks along with information about each task: (a) its priority level; (b) the typical time interval between successive requirements to perform the task during combat of low, moderate, and high intensity; and (c) the typical time required to perform the task given the number of launchers being controlled. The computer program operates upon the information contained in the task library to generate predictions of platoon leader performance. The indicators of performance generated by the model are all concerned in one way or another with how well the platoon leader is able to keep up with the tasks he is required to perform. The model was used in a simulation experiment to evaluate the effects of platoon size and level of combat intensity on CSWS platoon leader performance.

Findings:

Three launchers would be a reasonable number for a CSWS platoon leader to control; the number should not exceed four. The results of the simulation experiment also suggest that the model could be useful as a tool during the development of CSWS and other systems.

Utilization of Findings:

The simulation model is intended to be a tool to supplement the judgment of system developers by providing necessary but difficult to obtain information. The simulation model makes the user of the model aware of how task performance will be affected by what the platoon leader is asked to do and the conditions he is subjected to as he performs the tasks. The model users will need to be aware of factors that cannot be addressed by the simulation model, and to consider those factors in making decisions that affect platoon leader workload. The model presented here could be used to simulate the performance of a wide range of supervisors.

A DECISION AID FOR ADDRESSING SUPERVISOR SPAN OF CONTROL PROBLEMS

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INTRODUCTION

Background

In 1982, the Fort Sill Field Unit of the Army Research Institute (ARI) developed a method for estimating how many launchers a Corps Support Weapon System (CSWS) platoon leader will be able to control. The Director of the CSWS Special Task Force was concerned with the tradeoff between number of launchers controlled and platoon leader workload. To conserve resources, it would be desirable to have each platoon leader control many launchers. Increasing the number of launchers controlled, however, would also increase workload. At some point, the number would exceed what the platoon leader could adequately control, he would fall behind in completing his tasks, and the performance of the platoon would suffer.

Because CSWS was only at the concept definition phase of development, a computer-based simulation model was developed to address the tradeoff between number of launchers controlled and platoon leader workload. The model and the results of a simulation experiment were described in a report written for the Special Task Force (Coke & Greene, 1982). The research was conducted as part of an effort to develop tools for the analysis of new weapon systems.

Purpose

The purpose of this report is to describe the simulation model and to develop the concept of using the model as a decision aid during system development. Although the computer model will be discussed in terms of simulating CSWS platoon leader performance, it should be clear that the model could be used to simulate performance in other supervisory positions. The rest of the report describes the simulation model, its capabilities, and the use to which it could be put by system developers.

THE SIMULATION MODEL

The computer-based model consists of two components. The first component is a task library (see Appendix A); the second is a computer program that operates upon the data contained in the library (see Appendix B).

Task Library

Because the Organizational & Operational Concepts (O&O) for CSWS and the Multiple Launch Rocket System (MLRS) were to be similar, and because MLRS was much further along in its development than was CSWS, MLRS was used as a reference system to develop a task library. The training and

Doctrine Command (TRADOC) System Manager's Office for MLRS provided a draft field manual and a draft of the MLRS system organization, tactics, and techniques (SOTT) concept for OT-III so that we could identify the tasks to be performed by an MLRS platoon leader.

As we developed a task list, the tasks seemed to fall into two categories. In one category were tasks with clearly identifiable start and stop points, for example, performing a ground reconnaissance. In the second category were continually recurring tasks, for example, maintaining a situation map. Although one could ascertain at any given time whether a platoon leader is engaged in maintaining a situation map, this task is never really completed; it is performed, off and on, so long as combat continues.[1]

After the task list had been developed, it was verified as being complete by four subject matter experts from the TRADOC System Manager's (TSM's) Office. Information about these tasks was then developed through group discussions with the four subject matter experts. For all tasks, subject matter experts rated level of priority on a 5-point scale, with 5 being the highest priority. The subject matter experts also indicated for all tasks the relationship between task performance and number of launchers in a platoon (i.e., adding one launcher increases the time required to perform a task by 5 minutes).

For tasks with clear start and stop points, the subject matter experts reached a consensus response on two additional questions. The first question asked about the frequency with which each task would be performed during combat of low, moderate, and high intensity. As expected, the subject matter experts indicated that many tasks would be performed more frequently with increasing intensity of combat. They predicted, for example, that the platoon would average zero moves a day during combat of low intensity, three during combat of moderate intensity, and six during combat of high intensity. The second question asked the subject matter experts to predict the average time required to perform the tasks. For tasks that recur continually, the subject matter experts followed a slightly different procedure. They identified an appropriate unit of time, such as an hour or a day, and then reached a consensus on what amount of that time the recurring task would require during combat of low, moderate, and high intensity.

Computer Program

To estimate how many launchers a platoon leader can adequately control, it is not sufficient simply to know for each task the typical time interval between successive requirements to perform the task and the typical amount of time needed to perform it. One must also take into account random variation. By chance, the time interval between successive requirements to perform a particular task will sometimes be short and sometimes long; by chance, a platoon leader will sometimes perform a task rapidly and sometimes slowly.

It was to deal with the complexities created by random variation that we developed the computer program. The program simulates two sets of events. The first set of events simulated represents the task environment imposed on the platoon leader. In combat, each task for which a platoon leader is responsible will have to be performed repeatedly across time. For example, the platoon will have to move to a new location from time to time, and with each move the platoon leader will perform certain tasks. The computer program simulates this environment by scheduling task requirements at specific points in simulated time. Scheduling is based on the assumption that the variation around the typical time interval between successive requirements to perform each kind of task will follow the exponential probability distribution.[2]

The second set of events simulated represents the platoon leader's response to his task environment. In our simulation, when a requirement to perform a task occurs, either of two things can happen depending upon whether the platoon leader is free or busy. If the simulated platoon leader is free when the requirement occurs, he begins to work on the task immediately; that is, the simulation program uses the typical time required to perform the task to schedule the point in time at which the task will be completed. Scheduling is based on the assumption that variation around the typical time required to perform the task will follow the exponential probability distribution, the same distribution used in scheduling the time interval between tasks. Once the simulated platoon leader starts a task, he must complete it before beginning another.

If the platoon leader is busy when the requirement to perform a task occurs, the task is filed in the platoon leader's queue according to priority. Whenever the platoon leader completes a task, he checks his queue. If tasks are waiting, he begins to work on the task with the highest priority (and if two tasks have equal priority, on the one that has been in the queue longer); that is, the simulation program schedules the point in time at which the task will be completed. If the platoon leader finds no task in the queue, he remains idle until the next requirement to perform a task occurs.[3,4]

Capabilities of the Simulation Model

In Table 1 are listed three variables that the computer program can accept as input and four variables that it can produce as output. Each input variable is manipulated via the task library. Platoon leader task libraries for one, two, three, four, and five launcher platoons are shown in Appendix A. The library data entries are explained in the introductory material preceding the task libraries.

The variables output by the computer program are statistical indicators of platoon leader performance. They can be calculated for any period of time simulated--for an hour, a day, or a week. The statistics

TABLE 1

Input and Output Variables of the Simulation Model

Input Variables	Output Variables
1. Time required to complete individual tasks (would be used primarily to evaluate the effects of number of launchers controlled but could also be used to evaluate, for example, the effect of giving the platoon leader a tool that would allow him to perform some individual tasks more rapidly).	1. Average number of tasks in the queue waiting to be performed - by level of task priority if desired.
2. Time between requirements to perform tasks (would be used primarily to evaluate the effects of combat intensity).	2. Average length of time tasks spend in the queue waiting to be performed - by level of task priority if desired.
3. Tasks included in the library (would be used to evaluate the effects of the platoon leader delegating some tasks to others).	3. Average time required to complete all tasks waiting in the queue - that is, the time it would take the platoon leader to catch up with his work if he were to receive no new tasks.
	4. Average percentage of time platoon leader is idle or at least is free to perform tasks other than the mandatory ones included in the task library.

will, of course, vary from one run of the simulation program to the next, just as they would vary from one slice of time to the next for a real platoon leader. Estimates of the variance in the statistics are calculated by performing multiple simulation runs.

USE OF THE SIMULATION MODEL BY A SYSTEM DEVELOPER

The computer model was used in a simulation experiment to evaluate the effects on platoon leader performance of two input variables: (a) number of missile launchers controlled and (b) level of combat intensity. The simulation experiment provides a context for discussing the use of the simulation model as a decision aid and is briefly described here.

CSWS Simulation Experiment

To manipulate number of launchers controlled, separate task libraries were developed for one, two, three, four, and five launcher platoons (see Appendix A). Performance with each platoon size was assessed under two levels of combat intensity: moderate and high. The entries shown in the task libraries reflect the expectation that many individual tasks will take longer to perform as the number of launchers increases. The entries also reflect the expectation that many activities will be performed more frequently with increasing combat intensity, regardless of number of launchers controlled.

For each combination of number of launchers by level of combat intensity, thirty 12-hour periods were simulated. The relatively large sample was needed because of the probabalistic nature of the model; for any one combination of platoon size and combat intensity, considerable variation in platoon leader performance occurred from one 12-hour period to the next.[5]

Some results from the simulation experiment are shown in Table 2 and in Figures 1 and 2. Table 2 displays the mean number of tasks in the platoon leader's queue from hour 1 through hour 12 of simulated time for each combination of platoon size and level of combat intensity. Difficulty in keeping up with tasks is indicated by the increase over time in the number of tasks in the queue; greater difficulty is indicated by more rapid increases.

Figure 1 shows graphically the results for each of the platoon sizes during combat of moderate intensity. With platoons of one or two launchers, the size of the platoon leader's queue grows gradually over the 12-hour period, reaching an average size of about three tasks in hour 12. With platoons of three or four launchers, the queue grows slightly more rapidly, reaching an average size of about six and one-half tasks in hour 12. With a platoon of five launchers, the queue grows still more rapidly, reaching an average size of nearly 12 tasks in hour 12.

Table 2

Mean Number of Tasks in Queue during Each Hour of Simulated Time with the Platoon Leader Controlling Different Numbers of Launchers in Different Levels of Combat Intensity

Number of Launchers	Hour 1	2	3	4	5	6	7	8	9	10	11	12
MODERATE COMBAT INTENSITY												
ONE	.32	.75	1.26	1.33	1.21	1.27	1.70	2.24	2.53	2.79	2.69	3.23
TWO	.37	1.04	1.26	1.73	1.43	1.93	2.76	2.83	2.77	3.08	3.20	3.06
THREE	.61	1.57	2.12	3.20	4.13	4.19	3.36	3.04	3.40	4.25	5.58	6.46
FOUR	.67	1.04	1.39	1.76	1.92	2.34	3.00	3.45	3.87	4.43	5.89	6.72
FIVE	.70	1.88	2.57	3.54	4.86	5.44	5.79	7.09	8.52	9.74	10.60	11.78
HIGH COMBAT INTENSITY												
ONE	.82	1.92	2.66	2.99	3.47	3.91	5.00	6.06	7.30	8.22	9.44	9.81
TWO	1.20	2.48	3.32	4.90	5.62	8.07	9.90	10.95	11.08	10.88	11.26	11.57
THREE	1.15	2.72	3.62	4.73	5.75	7.30	8.73	9.62	10.62	12.06	13.87	15.45
FOUR	1.00	2.73	4.35	6.51	8.71	10.87	12.95	14.80	15.71	17.49	18.19	19.96
FIVE	1.38	3.53	5.57	7.58	8.73	9.82	11.73	13.74	15.85	17.14	19.19	21.68

NOTE. Each of the means is based on 30 observations.

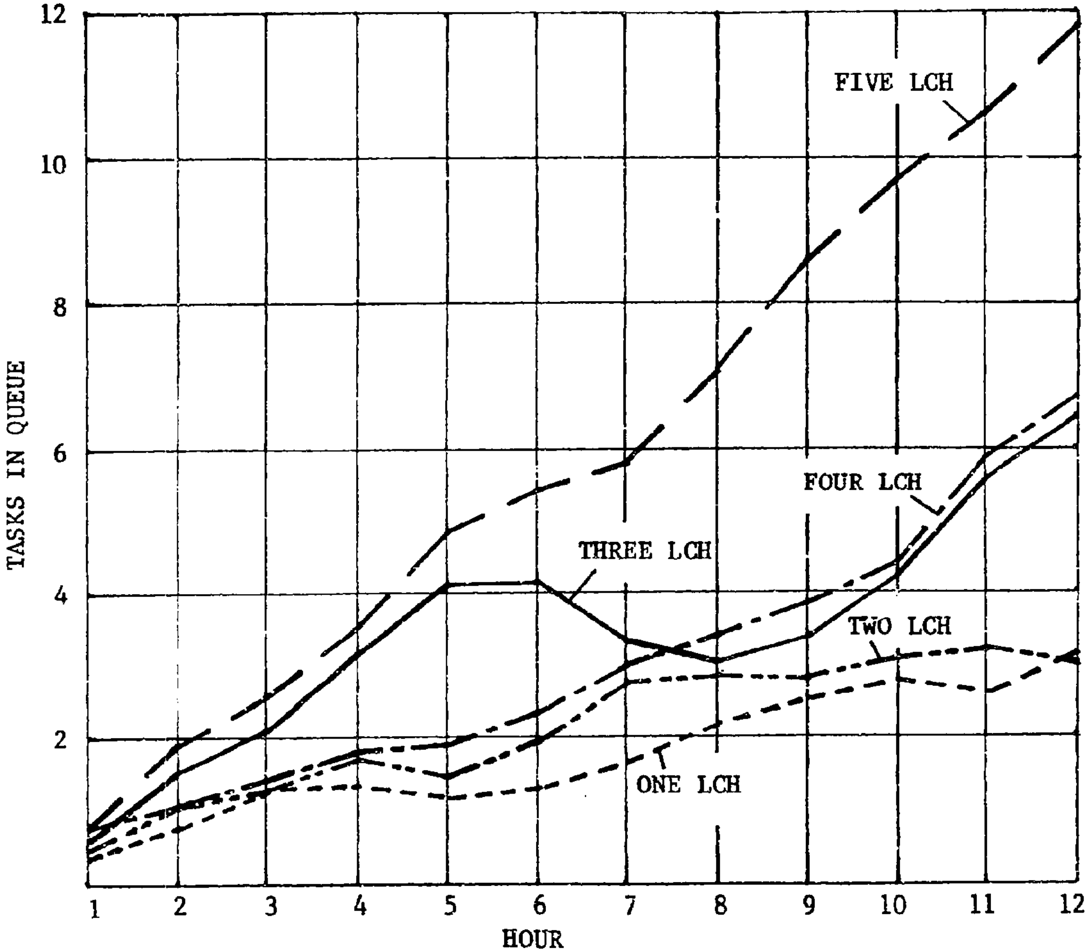

Figure 1. Mean number of tasks in the platoon leader's queue by hour in combat of moderate intensity with platoons of one through five launchers.

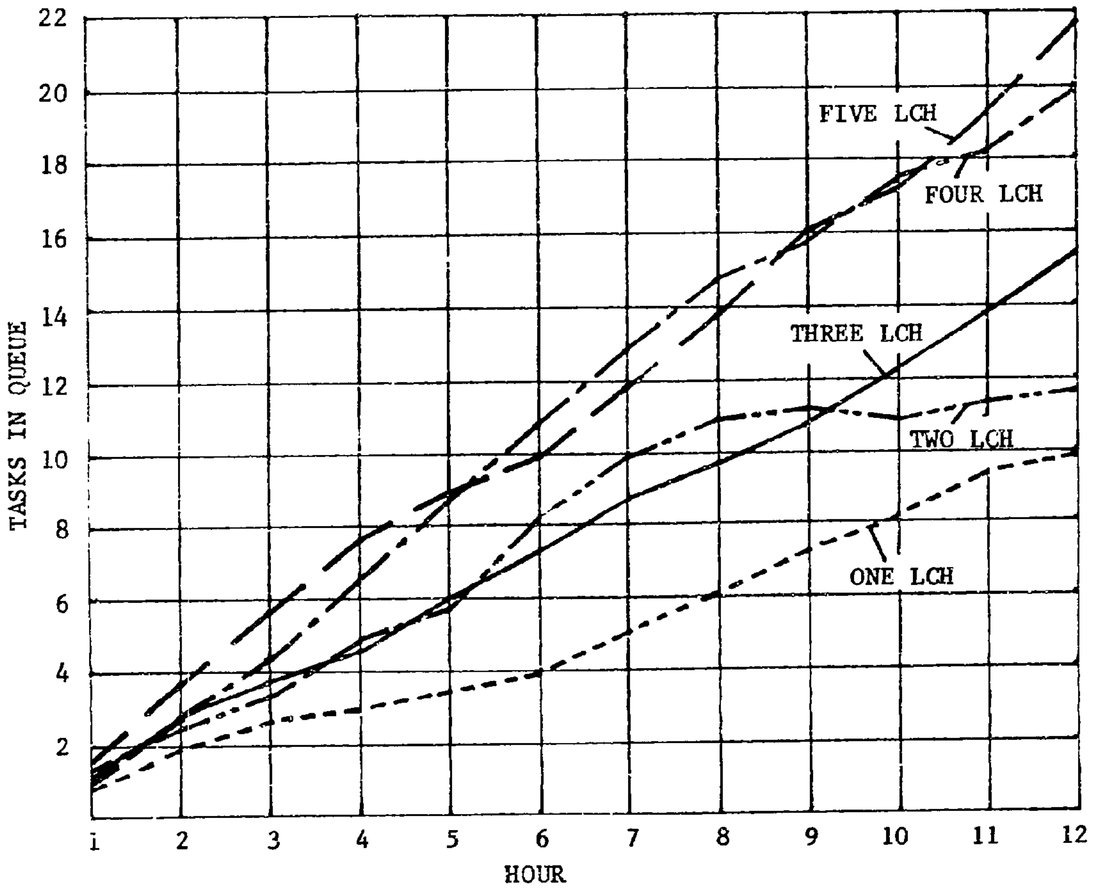

Figure 2. Mean number of tasks in the platoon leader's queue by hour in combat of high intensity with platoons of one through five launchers.

Figure 2 shows the results for the different platoon sizes during combat of high intensity. Note that the scale for number of tasks in Figure 2 is different from Figure 1. In combat of high intensity, the task queue grows fairly rapidly across the 12-hour period even for a platoon with only one launcher, reaching an average size of 9.81 tasks in hour 12. With platoons of four or five launchers, however, the queue grows much more rapidly, reaching an average size of about 20 tasks in hour 12. Performance with platoons of two or three launchers is at an intermediate level.[6]

Use of the Simulation Model

A system developer looking at the results shown in Table 2 and in Figures 1 and 2 might form the hypothesis that a CSWS platoon leader will generally have a heavy workload. Even when controlling only one or two launchers in combat of moderate intensity, the simulated platoon leader had some difficulty keeping up with his work. A system developer might also form the hypothesis that level of combat intensity will more powerfully influence platoon leader workload than will the number of launchers.

Given that the platoon leader's workload appears to be heavy, particularly during high intensity combat, a system developer might want to see what would happen if some of the platoon leader's tasks were delegated to others. This could be done simply by removing the delegated tasks from the task library and running the simulation program with the revised library. The system developer might also think that the platoon leader could perform some individual tasks more rapidly if he were given some new tools with which to perform those tasks. To see how this would affect platoon leader performance, the task library entries for the time required to complete the individual tasks would be changed.

A point that we want to emphasize is that the simulation model is intended not to replace the judgment of the system developer, but only to supplement that judgment by providing information that, without the model, could be generated only with great difficulty (see Keen, 1980). In this vein, our simulation model does not prescribe a definitive number of launchers that a platoon leader should control. Instead, it makes the user of the model aware of how task performance will be affected by what the platoon leader is asked to do and the conditions he is subjected to as he performs the tasks. The system developer will be aware of factors that cannot be addressed by the simulation model, and he or she will need to consider these factors also in making decisions that affect platoon leader workload.

In the case of estimating span of control for CSWS platoon leaders, we concluded from our simulation results that three launchers would be a reasonable number for a platoon leader to control and that the number of launchers controlled should not exceed four. The CSWS Task Force Director indicated that our data and conclusions were consistent with

a set of data from another source and of a different nature. The Director found it encouraging that the independent data sets seemed to suggest similar conclusions about platoon leader span of control.

SUMMARY

This report describes a computer model that simulates platoon leader performance under different levels of task load. The computer model is intended not to make decisions, but rather to serve as an aid to system developers. The system developer plays two roles in using the model. The first role is to develop task data for the supervisor position to be simulated. The second role is to interpret and use the statistical output of the simulation program within the overall context of what is known about the system being developed. Information about the simulation model is available through the Fort Leavenworth Field Unit of the Army Research Institute.

number of tasks in the queue and considering this number in conjunction with the typical times required to perform the activities in the task library, one can get a reasonably good idea of how well the platoon leader is keeping up with his work and of how far behind he is in terms of time. For example, the median activity time in the task library for a five-launcher platoon is 20 minutes. Thus, if a platoon leader has 10 tasks in his queue, he has probably fallen behind in his work by more than a trivial amount. As was indicated in Table 1, however, the model can generate precise measures of the average amount of time individual tasks spend waiting in the queue and the average amount of time that it would take the platoon leader to complete all the tasks waiting in his queue. A system developer might well want to look at these dependent measures. And he or she might want to break all the measures out by level of task priority--to see, for example, the average number of high priority tasks waiting in the queue across a period of time. The system developer would be free to choose the output variables at which to look and the level of detail on those output variables.

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APPENDIX A

Development of the Task Libraries

Twenty-three tasks were identified as being the responsibility of a platoon leader in a battery of the Multiple Launch Rocket System (MLRS). Each of these tasks was assigned a code number. Below is a list with the code number for each task and a brief description of the task.

LIST OF TASKS

CODE	DESCRIPTION
1	Performs a map reconnaissance
2	Receives displacement order by radio
3	Performs a ground reconnaissance of route and potential platoon area
4	Orders displacement and designates order of march
5	Organizes new platoon area
6	Coordinates establishment of platoon area survey point
7	Designates status of self-propelled launcher loaders
8	Supervises occupation of new position
9	Verifies location and accuracy of platoon area survey point
10	Insures that command post is in order and communication is established
11	Conducts coordination meetings
12	Maintains situation maps, overlays, and charts
13	Performs a ground reconnaissance of route and potential platoon area (Although this appears to be the same task as task 3, task 13 was included in the simulation analyses because the platoon leader will occasionally find a potential platoon area unsuitable for use. Task 13 was used to represent this occasional situation in the simulation analyses.)
14	Designates change in status of self-propelled launcher loaders when that status changes while the platoon is located within a particular platoon area

LIST OF TASKS (Continued)

CODE	DESCRIPTION
15	Supervises improvement of positions (On most occasions the platoon leader will perform this task simultaneously with the performance of other tasks involved in moving to a new position. For only about 25 percent of the moves will this be performed as a separate task.)
16	Controls vehicle traffic into and out of the platoon area
17	Insures that situation reports are prepared and sent to battery
18	Performs a hasty survey and calls it in (This task will occasionally be performed when the platoon moves to a new platoon area.)
19	Insures availability of NBC equipment
20	Engages in NBC alert and, when appropriate, issues all clear
21	Actively directs ammunition support
22	Actively directs maintenance support
23	Monitors medical support

Tasks 1 through 11 are tasks that are ordinarily performed when the platoon has to move to a new platoon area. These tasks were grouped together in one activity for purposes of the simulation analyses. Each time movement to a new position was scheduled in a simulation run, each of the 11 tasks had to be performed. The remainder of the tasks, tasks 12 through 23, were scheduled independently of one another and of the movement tasks in the simulation runs.

Below are the task libraries that were used to simulate the performance of a platoon leader controlling different numbers of launchers. A separate task library was used for each platoon size.

At least two lines are used to describe each activity represented in the task library. Each activity performed by a platoon leader was given a short descriptive name. This name appears as the alphabetic entry on the first line for each activity. Four numeric entries follow the name on the first line. The first numeric entry indicates the typical time span in minutes between requirements to perform the activity during combat of low intensity, the second numeric entry indicates the time span during combat of moderate intensity, and the third numeric entry indicates the time span during combat of high intensity. The fourth numeric entry on the first line indicates the priority of the

activity, larger numbers indicating higher priority. (Although the subject matter experts from the TSM's office rated the priority of the tasks from one to five, the values of priority in the task library go as high as nine. A greater spread in the range of priority values was needed for the computer program to operate properly.)

The line or lines below the first line for an activity are used to indicate the typical times required to perform the task or tasks associated with the activity. The first entry on these lines is the code number for the particular task. The second entry is the typical time in minutes required to perform the task. Only one activity, "MOVE", has multiple tasks associated with it. Whenever a move is scheduled to occur in a simulation run, each of the individual tasks associated with this activity has to be performed.

TASK LIBRARY FOR ONE LAUNCHER PLATOON

MOVE	1440	480	240	7
1	5			
2	1			
3	15			
4	3			
5	36			
6	1			
7	1			
8	15			
9	2			
10	3			
11	10			
OCCUPY	20	60	30	5
12	4			
SRECON	2880	1440	1440	7
13	15			
SDESIG	1440	480	240	7
14	1			
SSUPER	2880	1440	720	3
15	30			
STRAT	60	60	60	3
16	[illegible]			
SSTIRP	1440	1430	1440	6
17	15			
SHASTY	2880	1440	180	7
18	17			

TASK LIBRARY FOR ONE LAUNCHER PLATOON (Continued)

[illegible]	1440	1440	720	3
[illegible]	[illegible]			
[illegible]	2880	2880	2880	9
[illegible]	[illegible]			
[illegible]	2880	2880	1440	3
[illegible]	[illegible]			
[illegible]	1440	1440	1440	5
[illegible]	[illegible]			
[illegible]	1440	1440	1440	5
[illegible]	[illegible]			

TASK LIBRARY FOR TWO LAUNCHER PLATOON

[illegible]	1440	480	240	7
[illegible]	[illegible]			
[illegible]	[illegible]			
[illegible]	40			
[illegible]	[illegible]			
[illegible]	[illegible]			
[illegible]	[illegible]			
[illegible]	[illegible]			
[illegible]	40			
[illegible]	[illegible]			
[illegible]	[illegible]			
[illegible]	[illegible]			
[illegible]	70	60	50	5
[illegible]	[illegible]			
[illegible]	[illegible]	1440	1440	7
[illegible]	[illegible]			
[illegible]	1440	480	240	7
	[illegible]			
[illegible]	[illegible]	1440	720	3
	[illegible]			
[illegible]	60	60	60	3
[illegible]	[illegible]			
[illegible]	1440	1440	1440	6
	[illegible]			

TASK LIBRARY FOR TWO LAUNCHER PLATOON (Continued)

SHASTY	2880	1440	380	7
18	17			
SNBLPL	1440	1440	720	3
19	1			
SNALRT	2880	2880	2880	9
20	30			
SAMMO	2880	1440	720	3
21	6			
SMAINT	1440	1440	1440	5
22	40			
SMED	1440	1440	1440	5
23	20			

TASK LIBRARY FOR THREE LAUNCHER PLATOON

MOVE	1440	480	240	7
1	7			
2	1			
3	45			
4	3			
5	50			
6	1			
7	1			
8	45			
9	2			
10	3			
11	10			
OCCUPY	70	60	50	5
12	12			
SRECON	2880	1440	1440	7
13	45			
SDESIG	1440	480	240	7
14	1			
SSUPER	2880	1440	720	3
15	30			
STRAFF	60	60	60	3
16	2			
SSITRP	1440	1440	1440	6
17	15			
SHASTY	2880	1440	380	7
18	17			

TASK LIBRARY FOR THREE LAUNCHER PLATOON (Continued)

SNBCPL	1440	1440	720	3
19	1			
SNALRT	2880	2880	2880	9
20	30			
SAMMO	2880	960	480	3
21	6			
SMAINT	1440	1440	1440	5
22	60			
SMED	1440	1440	1440	5
23	20			

TASK LIBRARY FOR FOUR LAUNCHER PLATOON

MOVE	1440	480	240	7
1	8			
2	1			
3	50			
4	3			
5	57			
6	1			
7	1			
8	50			
9	2			
10	3			
11	10			
OCCUPY	70	60	50	5
12	16			
SRECON	2880	1440	1440	7
13	50			
SDESIG	1440	480	240	7
14	1			
SSUPER	2880	1440	720	3
15	30			
STRAFF	60	60	60	3
16	2			
SSITRP	1440	1440	1440	6
17	15			
SHASTY	2880	1440	380	7
18	17			

TASK LIBRARY FOR FOUR LAUNCHER PLATOON (Continued)

SNBCPL	1440	1440	720	3
19	1			
SNALRT	2880	2880	2880	9
20	30			
SAMMO	2880	720	360	3
21	6			
SMAINT	1440	1440	1440	5
22	80			
SMED	1440	1440	1440	5
23	20			

TASK LIBRARY FOR FIVE LAUNCHER PLATOON

MOVE	1440	480	240	7
1	9			
2	1			
3	55			
4	3			
5	63			
6	1			
7	1			
8	55			
9	2			
10	3			
11	10			
OCCUPY	70	60	50	5
12	20			
SRECON	2880	1440	1440	7
13	55			
SDESIG	1440	480	240	7
14	1			
SSUPER	2880	1440	720	3
15	30			
STRAFF	60	60	60	3
16	2			
SSITRP	1440	1440	1440	6
17	15			
SHASTY	2880	1440	380	7
18	17			

TASK LIBRARY FOR FIVE LAUNCHER PLATOON (Continued)

SNBCPL	1440	1440	720	3
19	1			
SNALRT	2880	2880	2880	9
20	30			
SAMMO	2880	576	288	3
21				
SMAINT	1440	1440	1440	5
22	100			
SMED	1440	1440	1440	5
23	20			

APPENDIX B

COMPUTER PROGRAM FOR SIMULATION MODEL

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```
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PREAMBLE
NORMALLY MODE IS REAL AND DIMENSION IS 0
PERMANENT ENTITIES
GENERATE LIST ROUTINES
  EVERY FUNCTION HAS A NAME, A USED.MEAN, A MEAN.ONE, A MEAN.TWO,
  A MEAN.THREE, A USED.SD, A SD.ONE, AN SD.TWO, AND AN SD.THREE,
  A PRIORITY AND OWNS A STRUCTURE
DEFINE NAME AS AN ALPHA VARIABLE
DEFINE PRIORITY AS AN INTEGER VARIABLE
EVERY RESOURCE HAS A STATUS AND OWNS A QUEUE
DEFINE STATUS AS AN INTEGER VARIABLE
TEMPORARY ENTITIES
EVERY ACTIVITY HAS AN ARRIVAL.TIME AND A JOB.PRIORITY, MAY BELONG
TO A QUEUE AND OWNS A ROUTING
DEFINE JOB.PRIORITY AS AN INTEGER VARIABLE
DEFINE QUEUE AS A SET RANKED BY HIGH JOB.PRIORITY
EVERY TASK HAS A CODE, A PROCESS.MEAN, A PROCESS.SD AND BELONGS TO
A STRUCTURE AND A ROUTING
DEFINE CODE AS AN INTEGER VARIABLE
EVENT NOTICES INCLUDE HOURLY.REPORT
AND CLEAN.OUT
EVERY START.ACTIVITY HAS AN ACTIVITY.TYPE
DEFINE ACTIVITY.TYPE AS AN INTEGER VARIABLE
EVERY END.OF.TASK HAS A JOB
DEFINE JOB AS AN INTEGER VARIABLE
EXTERNAL EVENTS ARE CHANGE.IN.SITUATION AND END.OF.SIMULATION
PRIORITY ORDER IS END.OF.TASK, START.ACTIVITY, HOURLY.REPORT,
CLEAN.OUT,
CHANGE.IN.SITUATION, AND END.OF.SIMULATION
BEFORE DESTROYING ACTIVITY CALL STAY.TIME
DEFINE STAY AS A REAL, DUMMY VARIABLE
TALLY AVG.STAY AS THE MEAN, SD.STAY AS THE STD.DEV,
SUM.STAY AS THE SUM, AND NUM.STAY AS THE NUMBER OF STAY
ACCUMULATE HSUM AS THE SUM, HNUM AS THE NUMBER,
AVG.QUEUE AS THE MEAN, MAX.QUEUE AS THE MAXIMUM,
AND FREQ (0 TO 30 BY 1) AS THE HISTOGRAM OF N.QUEUE
ACCUMULATE AVG.STATUS AS THE MEAN OF STATUS
END
```

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```
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MAIN
PRINT 1 LINE AS FOLLOWS
THE PLATOON LEADER IS CONTROLLING FIVE LAUNCHERS
PERFORM INITIALIZATION
RELEASE INITIALIZATION
FOR EACH FUNCTION, DO
CAUSE A START.ACTIVITY IN EXPONENTIAL.F(USED.MEAN,3) MINUTES
LET ACTIVITY.TYPE = FUNCTION
LOOP
CAUSE AN HOURLY.REPORT IN 1 HOUR
CAUSE A CLEAN.OUT IN 12 HOURS
START SIMULATION
SKIP 2 LINES
STOP
END
```

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```
ROUTINE FOR INITIALIZATION
READ N.RESOURCE
CREATE EVERY RESOURCE
FOR EVERY RESOURCE, DO
LET STATUS = 0
LOOP
LIST ATTRIBUTES OF EACH RESOURCE
READ N.FUNCTION
CREATE EVERY FUNCTION
FOR EACH FUNCTION, DO
READ NAME(FUNCTION), MEAN.ONE(FUNCTION), MEAN.TWO(FUNCTION),
MEAN.THREE(FUNCTION), SD.ONE(FUNCTION), SD.TWO(FUNCTION),
SD.THREE(FUNCTION), PRIORITY(FUNCTION)
LET USED.MEAN = MEAN.TWO
LET USED.SD = SD.TWO
UNTIL MODE IS ALPHA, DO THIS
CREATE A TASK
READ CODE(TASK) AND PROCESS.MEAN(TASK)
FILE THE TASK IN STRUCTURE
LOOP
LOOP
LIST ATTRIBUTES OF EACH FUNCTION
SKIP 2 LINES
RETURN
END
```

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```
EVENT START.ACTIVITY(FUNCTION) SAVING THE EVENT NOTICE
DEFINE PIECE AS AN INTEGER VARIABLE
CREATE AN ACTIVITY
LET ARRIVAL.TIME = TIME.V
FOR EACH PIECE OF STRUCTURE, DO
CREATE A TASK
LET CODE = CODE(PIECE)
LET PROCESS.MEAN = PROCESS.MEAN(PIECE)
LET PROCESS.SD = PROCESS.SD(PIECE)
FILE TASK IN ROUTING
LOOP
LET JOB.PRIORITY = PRIORITY
NOW ATTEND.TO.ACTIVITY
SCHEDULE THE START.ACTIVITY(FUNCTION) IN
EXPONENTIAL.F(USED.MEAN,3) MINUTES
RETURN END
```

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* * * UNCLASSIFIED * * * * * * * * * * * * * * * * * *


```
ROUTINE TO ATTEND.TO.ACTIVITY
LET RESOURCE = 1
IF STATUS = 0
PERFORM ALLOCATION
RETURN
OTHERWISE FILE ACTIVITY IN QUEUE
RETURN
END
```

* * * UNCLASSIFIED * * * * * * * * * * * * * * * * * *

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```
ROUTINE FOR ALLOCATION
LET STATUS(RESOURCE) = 1
REMOVE THE FIRST TASK FROM THIS ROUTING
SCHEDULE AN END.OF.TASK GIVEN ACTIVITY IN
EXPONENTIAL.F(PROCESS.MEAN,2) MINUTES
DESTROY THE TASK
RETURN END
```

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```
UPON END.OF.TASK GIVEN JOB
LET STATUS(RESOURCE) = 0
DEFINE JOB AS AN INTEGER VARIABLE
LET ACTIVITY = JOB
IF ROUTING IS EMPTY
  DESTROY THIS ACTIVITY
GO TO OPTION
OTHERWISE
ADD 1 TO JOB.PRIORITY(ACTIVITY)
FILE ACTIVITY IN QUEUE
'OPTION' IF QUEUE(RESOURCE) IS NOT EMPTY
REMOVE THE FIRST ACTIVITY FROM QUFUE
PERFORM ALLOCATION
ALWAYS
RETURN
END
```

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```
ROUTINE FOR STAY.TIME GIVEN ACTIVITY
DEFINE ACTIVITY AS AN INTEGER VARIABLE
LET STAY = TIME.V - ARRIVAL.TIME(ACTIVITY)
RETURN END
```

• • • UNCLASSIFIED •

• • • UNCLASSIFIED •

[illegible]

1 [illegible]
2 [illegible]
[illegible]
4 [illegible]
5 [illegible]
6 [illegible]
7 [illegible]
8 [illegible]
9 [illegible]
10 [illegible]
11 [illegible]
12 [illegible]
13 [illegible]
14 [illegible]
15 [illegible]
16 [illegible]
17 [illegible]
18 [illegible]
19 [illegible]
20 [illegible]
21 [illegible]
22 [illegible]
23 [illegible]
[illegible]
25 [illegible]
26 [illegible]
27 [illegible]
28 [illegible]

[illegible] 06/16/82

[illegible] IN EV,NIL,START,ACTIVITY)

[illegible]

* * * UNCLASSIFIED * * * * * * * * * * * * * * * * * * *

```
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   EVENT FOR HOURLY.REPORT SAVING THE EVENT NOTICE
   SKIP 2 LINES
   PRINT 1 LINE WITH HOUR.F(TIME.V) AS FOLLOWS
HOURLY REPORT FOR HOUR ***
   SKIP 2 OUTPUT LINES
   PRINT 2 LINES WITH AVG.STAY, SD.STAY, SUM.STAY AND NUM.STAY AS FOLLOWS
JOB STAY STATISTICS ARE      AVG.STAY = **.******    SD.STAY = **.******
                             SUM.STAY = **.******    NUM.STAY = **.******
   SKIP 2 LINES
   BEGIN REPORT
   BEGIN HEADING
   PRINT 2 LINES AS FOLLOWS
                          RESOURCE QUEUEING REPORT
  RESOURCE              AVG.QUEUE              MAX.QUEUE                 HNUM
   END
   FOR EACH RESOURCE, PRINT 1 LINE WITH RESOURCE, AVG.QUEUF,
   MAX.QUEUE, HNUM AS FOLLOWS
     **                   **.**                  **.**                   **.**
   END
   RESET TOTALS OF STAY
   FOR EACH RESOURCE, DO
   RESET TOTALS OF N.QUEUE
   LOOP
   LET RESOURCF = 1
   RESCHEDULE THIS HOURLY.REPORT IN 1 HOUR
   RETURN END
```

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LINE CACI SIMSCRIPT II.5 1100 SERIES RELEASE 7.0 06/16/82

```
EVENT CLEAN.OUT SAVING THE EVENT NOTICE
FOR EACH ACTIVITY IN QUEUE, DO
FOR EACH TASK IN ROUTING, DO
REMOVE THE FIRST TASK FROM ROUTING
DESTROY THE TASK
LOOP
REMOVE THE ACTIVITY FROM THE QUEUE
DESTROY THE ACTIVITY
LOOP
RESET TOTALS OF STAY
RESET TOTALS OF N.QUEUE
SKIP 2 LINES
PRINT 1 LINE AS FOLLOWS
A CLEAN OUT HAS OCCURRED
RESCHEDULE THIS CLEAN.OUT IN 12 HOURS
RETURN END
```